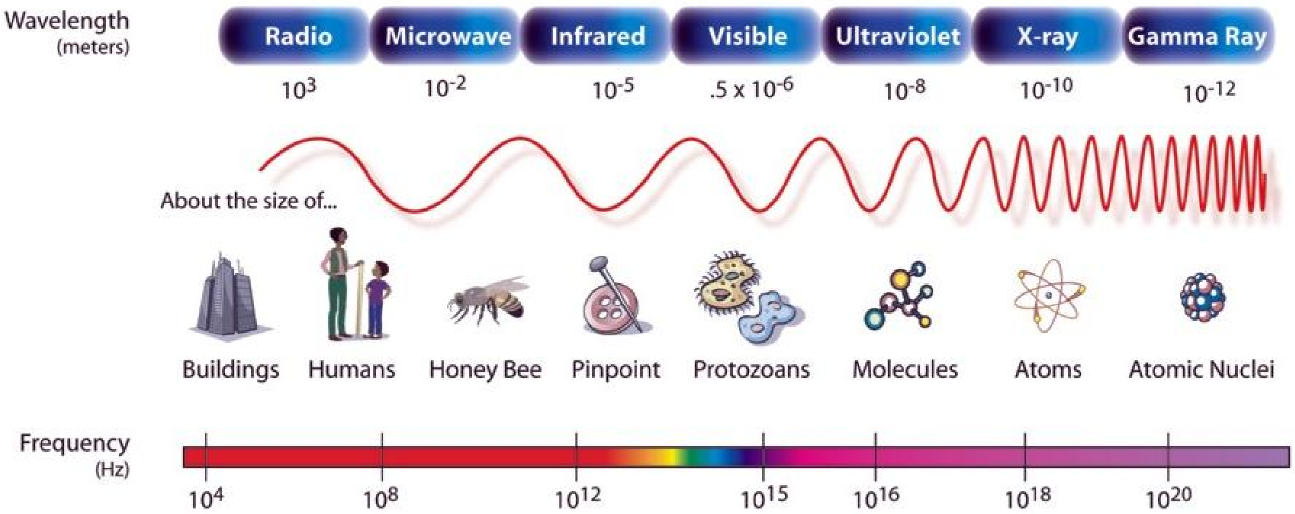
UNIT 3 REVIEW #1: EMR

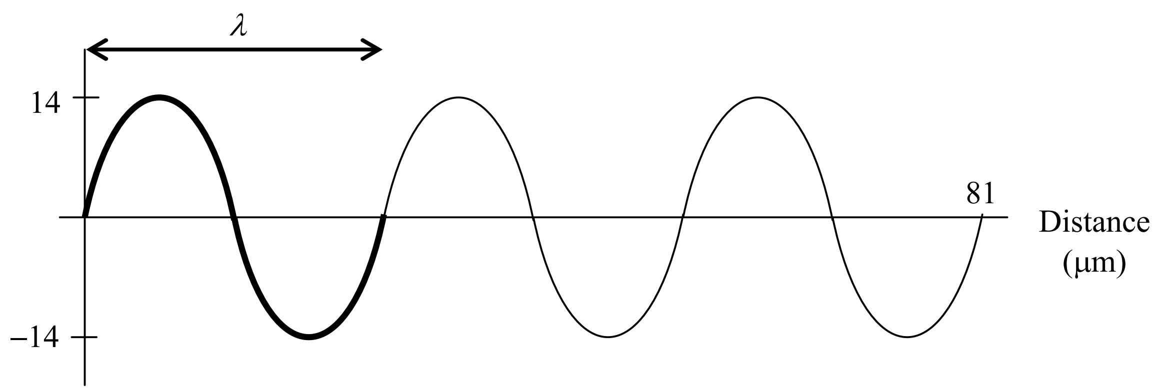
1.



So, in order of increasing frequency:

Radio Microwave Infrared Visible Ultraviolet X-Rays

2.

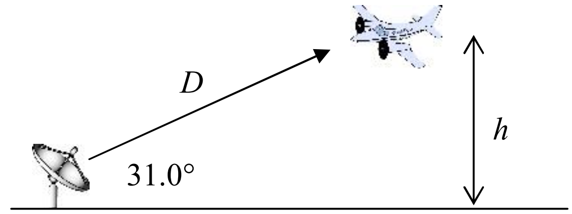


$$\lambda = \frac{1}{3}(81\ \mu m) \quad = \quad 27\ \mu\text{m}$$

$$v = f\lambda \qquad f = \frac{v}{\lambda} = \frac{c}{\lambda} \quad = \quad \frac{3.00\times10^{8}\ m/s}{27\times10^{-6}\ m} \quad = \quad 1.111\times10^{13}\ \text{Hz}$$

$$f = \frac{1}{T} \qquad T = \frac{1}{f} \quad = \quad \frac{1}{1.111\times10^{13}\ Hz} \quad = \quad 9.0\times10^{-14}\ \text{s}$$

3. Since the radar travels there and back (i.e. $2D$) in 6.20 μs at the speed of light,



$$v = \frac{d}{t} \qquad c = \frac{2D}{t} \qquad ct = 2D$$

$$D = \frac{ct}{2} = \frac{(3.00\times10^{8}\,m/s)(6.20\times10^{-6}\,s)}{2} = 930\text{ m}$$

Then, $\sin\theta = \dfrac{h}{D}$ $\quad h = D\sin\theta = (930\text{ m})\sin 31.0° = 479\text{ m}$

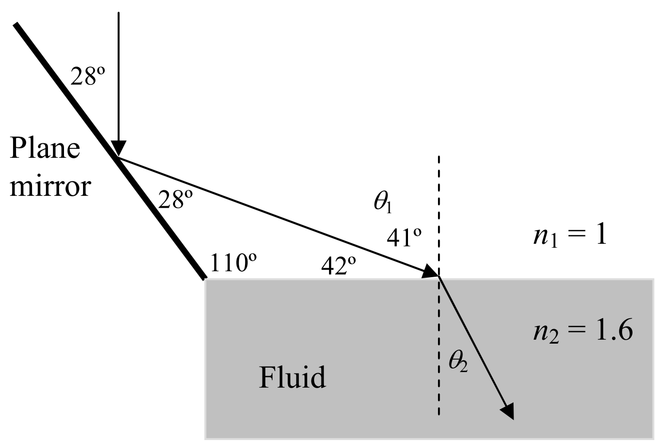
4. $f = \dfrac{1.10\times10^{5}\,rev}{60\,s} = 1833.33\text{ Hz}$; $T = \dfrac{1}{f} = \dfrac{1}{1833.33\,Hz} = 5.4545\times10^{-4}\text{ s}$

The light travels there and back (i.e. $2D$) in the time it takes for 1/8 of a revolution. Thus,

$$v = \frac{d}{t} \qquad v = \frac{2D}{\frac{1}{8}T} \qquad v = \frac{16D}{t} \qquad vt = 16D$$

$$D = \frac{vt}{16} = \frac{(2.7\times10^{8}\,m/s)(5.4545\times10^{-4}\,s)}{16} = 9204.5\text{ m} = 9.2\text{ km}$$

5. a) When the light enters a more dense medium, it bends towards the normal.



b) When the light reflects off the mirror, the reflected ray is symmetrical. Then, the angles in a triangle add up to 180°.

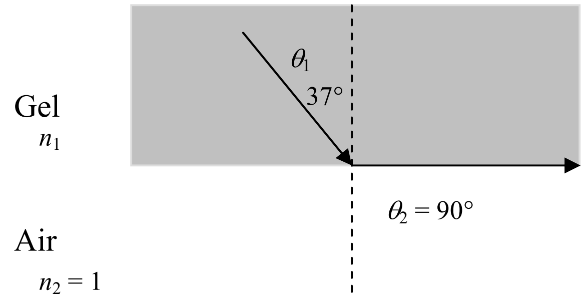
Finally,

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1} \qquad n_1\sin\theta_1 = n_2\sin\theta_2$$

$$\sin\theta_2 = \frac{n_1\sin\theta_1}{n_2} = \frac{(1)\sin 41°}{1.6}$$

$$\theta_2 = \sin^{-1}(0.41) = 24°$$

6. If it is a critical angle:
   - the ray is moving from slow to fast (i.e. gel to air)
   - the angle of refraction is 90°



a) $\dfrac{\sin\theta_1}{\sin\theta_2} = \dfrac{n_2}{n_1}$ $\qquad n_1 \sin\theta_1 = n_2 \sin\theta_2$

$$n_1 = \frac{n_2 \sin\theta_2}{\sin\theta_1} = \frac{(1)\sin 90°}{\sin 37°} = 1.66$$

b) $n_1 = \dfrac{c}{v_1}$ $\qquad v_1 = \dfrac{c}{n_1} = \dfrac{3.00\times10^8\, m/s}{1.66164} = 1.8054 \times 10^8$ m/s

$v = \dfrac{d}{t}$ $\qquad t = \dfrac{d}{v} = \dfrac{0.54\, m}{1.8054\times10^8\, m/s} = 2.99 \times 10^{-9}$ s

7. a) $n = \dfrac{c}{v}$ $\qquad v = \dfrac{c}{n}$ $\qquad v \propto \dfrac{1}{n}$

   Speed and index of refraction have an inverse relationship. Thus, if the index of refraction increases, then the speed decreases. It is going from fast to slow.

   b) Frequency never changes once it leaves the source vibration.
   Thus, frequency remains the same.

   c) $v = f\lambda$ $\qquad \lambda = \dfrac{v}{f}$ $\qquad \lambda \propto v$ $\qquad$ (since frequency remains constant)

   Wavelength has a direct relationship with speed. Thus, if the speed decreases, then the wavelength decreases as well.

8. a) $f = +24$ cm (converging mirror: real focus) ; $d_o = +35$ cm (real) ; d_i ?

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \qquad \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{24} - \frac{1}{35} = 0.013$$

$$d_i = \frac{1}{0.013} = +76 \text{ cm (real)}$$

   b) Since the image distance is positive, the image is real.
   Real images are always inverted.

9. a) $h_o = +72$ cm (upright) ; $d_o = +50$ cm (real)

$$R = 2f \qquad f = \frac{R}{2} = -\frac{30cm}{2} = -15 \text{ cm} \text{ (diverging mirror: virtual focus)}$$

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \qquad \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{-15} - \frac{1}{50} = -0.08667$$

$$d_i = -\frac{1}{0.08667} = -11.538 \text{ cm (virtual image)}$$

$$\frac{h_i}{h_o} = -\frac{d_i}{d_o} \qquad h_i = -\frac{h_o\, d_i}{d_o} = -\frac{(72)(-11.538)}{50} = +17 \text{ cm (upright)}$$

b) Since the distance to the image is negative, the image is virtual.
Virtual images are always upright.

10. $h_i = +22$ cm (upright, since virtual) ; $d_i = -10$ cm (virtual)

$$R = 2f \qquad f = \frac{R}{2} = +\frac{60cm}{2} = +30 \text{ cm (converging mirror: real focus)}$$

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \qquad \frac{1}{d_o} = \frac{1}{f} - \frac{1}{d_i} = \frac{1}{30} - \left(\frac{1}{-10}\right) = 0.13333$$

$$d_o = \frac{1}{0.13333} = +7.5 \text{ cm (real)}$$

$$\frac{h_i}{h_o} = -\frac{d_i}{d_o} \qquad h_i\, d_o = -h_o\, d_i \qquad h_o = \frac{h_i\, d_o}{-d_i}$$

$$h_o = \frac{(22)(7.5)}{-(-10)} = +16.5 \text{ cm} = +17 \text{ cm (upright)}$$

11. $f = -32$ cm (diverging lens: virtual focus)

Mag = +0.50 = $+\frac{1}{2}$ (upright, since virtual images are always upright

$$mag = -\frac{d_i}{d_o} \qquad \frac{1}{2} = -\frac{d_i}{d_o} \qquad d_o = -2d_i$$

Sub this into $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$, and we have

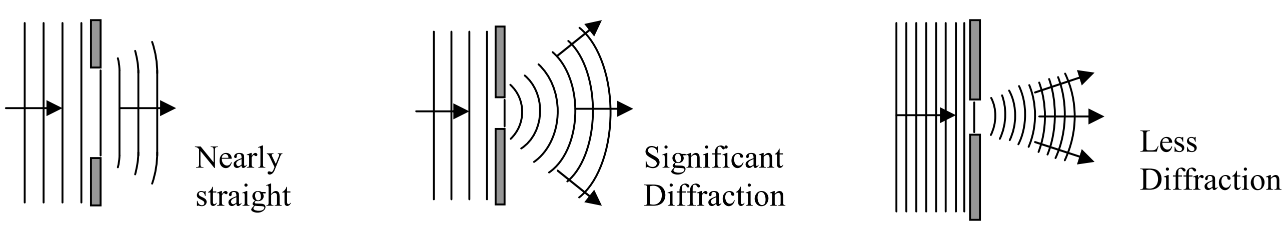
$$\frac{1}{-2d_i} + \frac{1}{d_i} = \frac{1}{-32} \qquad -\frac{1}{2d_i} + \frac{2}{2d_i} = \frac{1}{-32} \qquad \frac{1}{2d_i} = \frac{1}{-32}$$

$$2d_i = -32 \qquad d_i = -16 \text{ cm} \quad \text{(virtual)}$$

Finally, $d_o = -2d_i$ = −2 (−16 cm) = +32 cm (real)

12. a) Microwaves have a longer wavelength (see diagram for #1).
Longer wavelengths diffract more.

b) There is more diffraction when the slit is narrow.



13. $v = f\lambda$ $\qquad \lambda = \frac{v}{f} = \frac{c}{f} = \frac{3.00\times10^{8}\,m/s}{6.20\times10^{14}\,Hz} = 4.8387\times10^{-7}$ m

$$\frac{d}{1\,slit} = \frac{1\,mm}{150\,slits} \qquad d = \frac{1\times10^{-3}\,m}{150} = 6.6667\times10^{-6}\text{ m}$$

$n = 2$

Thus, $\lambda = \frac{d\sin\theta}{n} \qquad n\lambda = d\sin\theta \qquad \sin\theta = \frac{n\lambda}{d}$

$$\sin\theta = \frac{(2)(4.8387\times10^{-7})}{6.6667\times10^{-6}} = 0.145$$

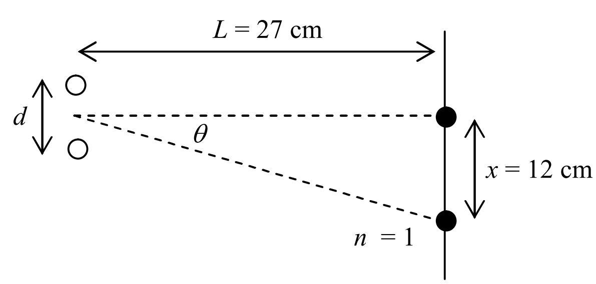
$$\theta = \sin^{-1}(0.145) = 8.35°$$

14. $\lambda = 550\times10^{-9}$ m $= 5.50\times10^{-7}$ m ; $d = 8.1\times10^{-6}$ m ; $L = 0.90$ m ; $n = 1$

$$\lambda = \frac{dx}{nL} \qquad nL\lambda = dx \qquad x = \frac{nL\lambda}{d}$$

$$x = \frac{(1)(0.90\,m)(5.50\times10^{-7}\,m)}{8.1\times10^{-6}\,m} = 0.061\text{ m} = 6.1\text{ cm}$$

15. The angle is greater than 10°, so you cannot use $\lambda = \frac{dx}{nL}$.



$$\tan\theta = \frac{12}{27} \qquad \theta = \tan^{-1}(0.444) = 23.96°$$

$$\lambda = \frac{d\sin\theta}{n} \qquad n\lambda = d\sin\theta$$

$$d = \frac{n\lambda}{\sin\theta} = \frac{(1)(430\times10^{-9}\,m)}{\sin 23.96°} = 1.1\times10^{-6}\text{ m}$$

$= 1.1$ μm

16. $v = f\lambda$ $\lambda = \frac{v}{f} = \frac{c}{f} = \frac{3.00 \times 10^8\, m/s}{7.5 \times 10^9\, Hz}$ = 4.0×10^{-2} m = 4.0 cm

Since the receiver is 12 cm away from transmitter 1, it is three wavelengths away.
Since the receiver is 18 cm away from transmitter 1, it is 4.5 wavelengths away.

If both transmitters sent out a crest, then the receiver would receive a crest from transmitter 1, but it would receive a trough from transmitter 2.

This is destructive interference, and so, it would be a weak signal.

17. Wave behaviour of EMR:

refraction (from fast to slow, it bends towards the normal)
polarization
travels at 3.00×10^8 m/s (particles cannot travel this fast)
diffraction

Note: Particles and waves can both travel through the vacuum of space.
Particles and waves both display the law of reflection.